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Light Rail Transit in Boston - Symbol of a New Era

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Boston has attracted considerable attention of transportation experts in recent years. The technical modernization of its transit system, especially of the light rail transit (LRT), is only one of the reasons for this attention. Equally significant has been a "revolution" in attitudes and policies toward urban transportation which has had a major impact on many cities across the United States, as well as in other countries. Boston's leadership in the 1970's, however, is not a new phenomenon.

Tradition of progressive public transport policies

In 1895, at the time the second subway in the world, Budapest, was being built (London's subway had been in operation since 1863), Boston began to build its first transit tunnel. When completed in 1897, the Boylston and Tremont tunnel became the first subway in the Western Hemisphere. It also became the first subway in the world which served streetcars converging from a wide network of lines. Thus, Boston was the inventor of the basic concept which later evolved in the transit mode we today refer to as *light rail transit*.

During the first decades of this century Boston pursued a very progressive policy in transit planning: its goal was to provide exclusive rights-of-way for transit in the congested central city area. Additional tunnels and elevated structures were built for rail transit. The "Central Subway," serving streetcars, was extended over a viaduct and bridge across the Charles River to Litchmere in the north (1912), and by new tunnel extensions to several branches in the south (1914 to 1941). Three separate rapid transit lines were also built in this period. Regional rail (commuter railroad) services from two center city stations (North Station and South Station) have been developed into 10 radial lines (their further extensions are presently under study). The three different modes, streetcars, rapid transit and regional rail, have common stations in the center city which permit transfers.

The Central Subway grew into a unique facility and, with time, followed a typical transition from streetcar to LRT mode. Being the joint section for a large number of lines converging toward the center city, the Subway had to handle a very high frequency of vehicles. Initially, only single cars were operated and records show that as many as 195 vehicles per hour operated in each direction during the peak hour, *i.e.* an average headway of some 18 seconds was achieved.

The Subway was built with some auxiliary tracks (short 4-track sections, turnarounds, etc.--*see* Fig. 1) to handle this phenomenal frequency.

Vehicle driving in the Subway was on visibility, and therefore at limited speeds only. Already in 1915 two-car, and later 3-car trains were introduced to increase capacity and speed by operation with longer headways. Thus, in 1947 98 trains with 206 cars per hour were operated. In 1970 this volume was decreased to 66 trains with 164 cars per hour, *i.e.* an average train length of 2.5 cars. All cars were 4-axle PCC cars, each with a driver or conductor aboard to collect fares. Present plans are to change gradually to trains of two 6-axle articulated cars, with capacity equivalent to three 4-axle cars, operating with full signalization in all critical areas (switches and crossings particularly).

Transit decline in the U.S.A.: 1950 to 1970

During the post-World War II period, the automobile ownership in the United States grew rapidly, and virtually all improvements in urban transportation were aimed at accommodating the automobile: extensive freeways were built around, into and through cities; streets were widened, parking garages built and their use was often provided at no cost to many employees, visitors and shoppers. These actions, naturally, resulted in decreasing transit ridership. Transit agencies, however, had no public financial assistance and were forced to reduce their services, further stimulating diversion of passengers to the private automobile.

Financial crisis of transit agencies prevented construction of new tunnels and rail lines; it forced the agencies to use the modes which required the minimum investment, even if their performance was lower and total cost of their operation over many years higher. Instead of utilizing different transit modes, each one where it is best suited, cities were forced into extremely simplified solutions. The existing rapid transit systems in five U.S. cities were merely maintained; trolleybuses and streetcars were rapidly converted to diesel bus operations. Production of streetcar vehicles ceased in the United States in 1952, of trolleybuses in 1956. Buses were becoming nearly the exclusive mode of urban transit. Even they offered little variety and technical innovation: the models produced during the World War II were unchanged until 1959, when the "New Look" body design was introduced. This design has dominated the bus market in North America until 1978, and only now, following extensive effort by UMTA* there is significant innovation and some diversification in bus manufacturing.

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*UMTA = Urban Mass Transportation Administration, section of the Department of Transportation in charge of urban transit.

This deterioration of transit, predictably, resulted in major passenger losses. But it is significant to note how the losses were distributed among modes. The number of passengers carried by rapid transit in 1970 was 83% of the number carried in 1950; the sum of the streetcar, trolleybus and bus ridership in 1970 was only 36% of their 1950 ridership! This difference is easy to explain. Rapid transit, unaffected by traffic congestion, continued to offer high speed, reliable service, competitive with the service of the private automobile. Street transit, on the other hand, suffered from increasing traffic congestion, lack of priority treatments over auto traffic, loss of separated rights-of-way in many conversions from streetcars to buses, and lower riding comfort of buses compared with more spacious, quieter rail vehicles.

Substitution of buses for streetcars was in many cases logical and justified: on lightly traveled lines buses are much more economical; in congested traffic they operate better than streetcars; bus routes require no investment for extensions into newly developed areas. However, this substitution was made also in the cases where it was clearly detrimental to the transit service and where bus operation resulted in lower operational and economic efficiency, more harmful environmental effects, and in substantial losses of passengers. For example, fast streetcar operations in reserved medians were often substituted by slow bus services on streets with heavy traffic and no separation. The medians were converted into paved lanes. Thus separation of transit vehicles, the most important condition for good quality of their service and passenger attraction, was lost.

Boston could not completely avoid this trend. Its streetcars and trolleybuses were largely replaced by buses on streets. Even outer sections of several lines which went into the Central Subway were replaced by buses, so that passengers had to transfer between buses and streetcars at tunnel entrances. Streetcar vehicles and their parts could not be obtained, so that the reliability and comfort of service were decreasing continuously. The daily ridership, predictably, declined.

Despite all these problems, however, the lines utilizing the Central Subway continued to play an important role in the city. In 1959, while streetcars were still being eliminated from many cities, a railroad right-of-way between central Boston and its western suburbs was connected by a new ramp with the Central Subway, and a new line was added to the Central Subway system. This new 15.1 km long Riverside Line, having its own right-of-way without any street crossings, became the highest quality line of the system. It represented a typical LRT line, except that its rolling stock consisted of old PCC cars, rather than modern articulated vehicles, widely used in many European cities since the late 1950's.

The 'transportation revolution' in Boston

During the mid-1960's it became obvious that the all-out efforts to accommodate the private automobile in U.S. cities was a serious and expensive error. Continuous construction of freeways caused major disruption of life in cities; urban environments became less and less attractive for people to live in and travel into; traffic congestion did not decrease; deterioration of public transportation led to creation of two distinct classes of population with respect to mobility: those who had automobiles enjoyed improved travel; others, who depended on public transportation, were less mobile than they had been in the 1920's! Moreover, further efforts in the same direction obviously led to worsening, rather than solving of the transportation problems in our cities.

The "revolution" started most notably in San Francisco when its population rejected construction of several freeways which would have been disastrous to the city's world-famous character and beauty. But Boston also had a long controversy about the national trend of extensive building of urban freeways. This controversy culminated around 1970, when the Governor of Massachusetts imposed a moratorium on all freeway construction in the Boston Metropolitan Area and ordered that a complete reappraisal of transportation policies and plans be undertaken. This reappraisal, named Boston Transportation Plan Review (BTPR), came out in 1972 with findings and recommendations which can be described as "revolutionary" with respect to the previous trends. The major policies and actions which were suggested by BTPR and generally adopted by the state and the city included the following ones:

-Stopping the construction of most freeways in the Region. Only the freeways mostly built would be completed; others were eliminated from the plans.

-Greater emphasis on full utilization of surface streets and arterials through modern traffic regulation.

-Acceleration in improvements of transit facilities, including construction of new rail transit lines, modernization of the existing lines, purchase of new vehicles, *etc.*

-Disincentives to auto use in the city through increased parking charges and traffic control measures;

-Incentives to transit use through improved services, passenger information, monthly tickets partially paid by employers, etc.*

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*For further details about the BTPR, *see* Reference [6].

Boston's "transportation revolution" was followed, in various degrees and forms, by similar actions in most other cities. Urban freeway construction has been generally halted; various types of auto use disincentives have been implemented; and transit has been given a much more favorable treatment than it had received during the 1950's and 1960's.

These changes had a major influence on the choice of transit modes. With improved financing, increased attention to high quality of service and proper consideration of urban environment, cities began to employ a variety of transportation modes and organization methods, instead of the previous simplistic polarization between rapid transit and buses. Carpools and vanpools have been encouraged, various modes of paratransit introduced. Trolleybus services have been modernized and, in some cities, even expanded. However, the greatest change happened with respect to surface rail transit.

Streetcars which operate on streets in mixed traffic without priority treatments have serious problems and usually offer service inferior to that of buses. But if they are separated from other traffic (in medians, parks, pedestrian malls, etc), and given priority treatments at intersections, their role changes radically: they become superior in many characteristics to buses and trolleybuses operating in mixed traffic. Rail system with largely separated rights-of-way and high-capacity, high-speed, quiet vehicles represent quite a different mode than old-fasioned streetcars. Such systems are designated "Light Rail Transit" (German: "Stadtbahn," French: "Metro Leger"). This mode has been extensively developed form the old streetcar systems in many German, Dutch, Swiss, Belgian and other cities in Europe, notably those which worked continuously on modernization of their transit systems (*see* References [4, 10, 11 and 12]).

Boston's Green Line

When the present transit agency in Boston, Massachusetts Bay Transportation Authority (MBTA) was founded in 1964, it introduced popular designations for its rail lines. The three rapid transit lines were named red, blue, and orange; all the lines using the Central Subway were collectively designated *The Green Line* (*see* Fig. 2).

In the early 1970's, as the transit improvement program was initiated, MBTA embarked on a major modernization of the Green Line, its upgrading into an LRT system. This effort, still under way, has consisted of the following actions:

-Purchase of 175 articulated vehicles;

-Total reconstruction of 100 old PCC cars (presently 18 are being worked on);

-Reconstruction of tracks on the Riverside Line;

-Introduction of new communication and signal systems;

-Construction of three new electric substations;

-Construction of a new maintenance facility at the Riverside Terminal.

The total cost of these improvements up to date has amounted to about $172 million. UMTA's assistance in this program, although often slow and with very complex requirements for many studies, has been substantial and crucial.

The procedure of purchasing the new LRT vehicles was particularly interesting. Both Boston and San Francisco realized around 1970 that in order to modernize their streetcar systems into LRT, they must improve not only rights-of-way, but also their rolling stock. Based on the reports about LRT development in Europe (particularly References [3 and 11]), and with organizational and financial assistance from UMTA, the two cities ordered 275 6-axle articulated LRT vehicles from the Boeing Vertol Company in Philadelphia.

By its basic design and operational features the Boeing vehicles are drastically different from the PCC cars. They resemble the modern European LRT vehicle, as can be seen in Fig. 3 and in Photo. 1. Their basic technical data are:

Body length	21.64 m	Max. speed	84 km/h
Body width	2.70 m	Max. grade	9%
Empty weight	30.4 tonnes	Max. acceleration	1.4 m/s^2
Seating capacity	68	Regular braking	1.6 m/s^2
Standing capacity (at 0.20 m^2/standee)	98	Emergency braking	2.7 m/s^2
Motor power	2 × 168 KW	Min. turning radius	14 m.

After decades of neglect and lack of improvements of transit systems, major modernization is difficult to make rapidly. It requires extensive technical expertise, organizational innovations and education of the public. Boston has been having some of the problems caused by modernization after long neglect. The vehicles have had a number of technical difficulties, requiring extensive adjustments; fare collection has not been modernized to allow faster boarding, badly needed on the high capacity vehicles; due to various traditions

and labor union rules, each LRT vehicle in a multi-car train still has an employee, partially defeating the higher productivity of train operations. Yet, with all these remnants of the past and less than half of the new LRT vehicles in service, the impacts of these modernization measures have been very significant: the ridership decline on the Green Line has been reversed; an increase of ridership of about 20% has already taken place.

The Green Line presently has a line length of 44 km, with 16.4% in subway, 39.0% on exclusive right-of-way, 35.0% in street medians 9.6% in streets. Total length of its four routes is 58 km. In addition, a separate LRT line in the southern part of the city, Mattapan (*see* Fig. 2) is 4.2 km long, and has an exclusive right-of-way. The Green Line with some 180,000 daily passengers, carries more people than any one of the three rapid transit lines. Its great advantage is the extensive area coverage the four branch lines offer, as Fig. 4 shows, and a good distribution in the city center. High frequency service easily accessible on streets, and yet with relatively high speed (operating speeds on the lines are between 16 and 25 km/h, with the overall average of 20 km/h), and an excellent image, make this system very attractive to passengers. Park-and-ride lots along the Riverside Line are always well utilized. When additional new vehicles will be placed into service, fare collection eventually improved, and further modernization completed, it is expected that the Green Line will become an excellent LRT system, the most important set of lines in this metropolitan area with a population of 2.9 million.

Current development of light rail transit in other cities

For many years the LRT mode had been systematically developed in several European countries, without much notice elsewhere. In great Britain, France, Spain, most of Latin America and many other parts of the globe it was believed that streetcars disappeared forever and that the only rail transit modes of the future are rapid transit and regional rail (suburban railroads). This opinion changed drastically and rapidly as a consequence of several developments.

Changes in attitudes toward transit described above led to the conclusion that bus services can be improved in most cities, but they cannot satisfy the needs for high-quality service in many medium and large cities. Rapid transit is an excellent solution - but its high investment requirements limit its applications to large and some medium cities. There is a large number of cities which need a service better than that buses can offer, but which cannot afford rapid transit. Examples of Rotterdam, Frankfurt, Mannheim, Gothenburg and many other medium-size cities show that LRT represents the transit mode most suitable to efficiently "fill the gap" between low-investment/low-service quality buses, and high-investment/high-service quality rapid transit.

Hardly recognized as a mode in the United States in 1970, LRT is presently being developed not only in Boston and San Francisco, but also in Pittsburgh, Cleveland and Philadelphia from the existing streetcar systems; new lines are being built in Buffalo and planned in Portland, San Diego, and a number of other U.S. cities. Canada has one new system in operation (Edmonton), one under construction (Calgary), several in planning (Toronto, Ottawa, Vancouver). New LRT systems are also under construction or in planning in many cities around the world: in Utrecht, Kiev, Cairo, Hong Kong, Adelaide, Rio de Janeiro, Lima, and a number of French cities. Many new vehicle designs, such as the 8-axle doubel-articulated cars in Photos. 2 and 3, have been developed for the existing and new systems in recent years.

Recent transportation developments in Boston thus symbolize a new era in both urban transportation policies, and in technical/-operational innovations of rail transit systems. Results of these changes have only begun to be realized; most of the benefits of the current progress should be expected to occur in the coming years.

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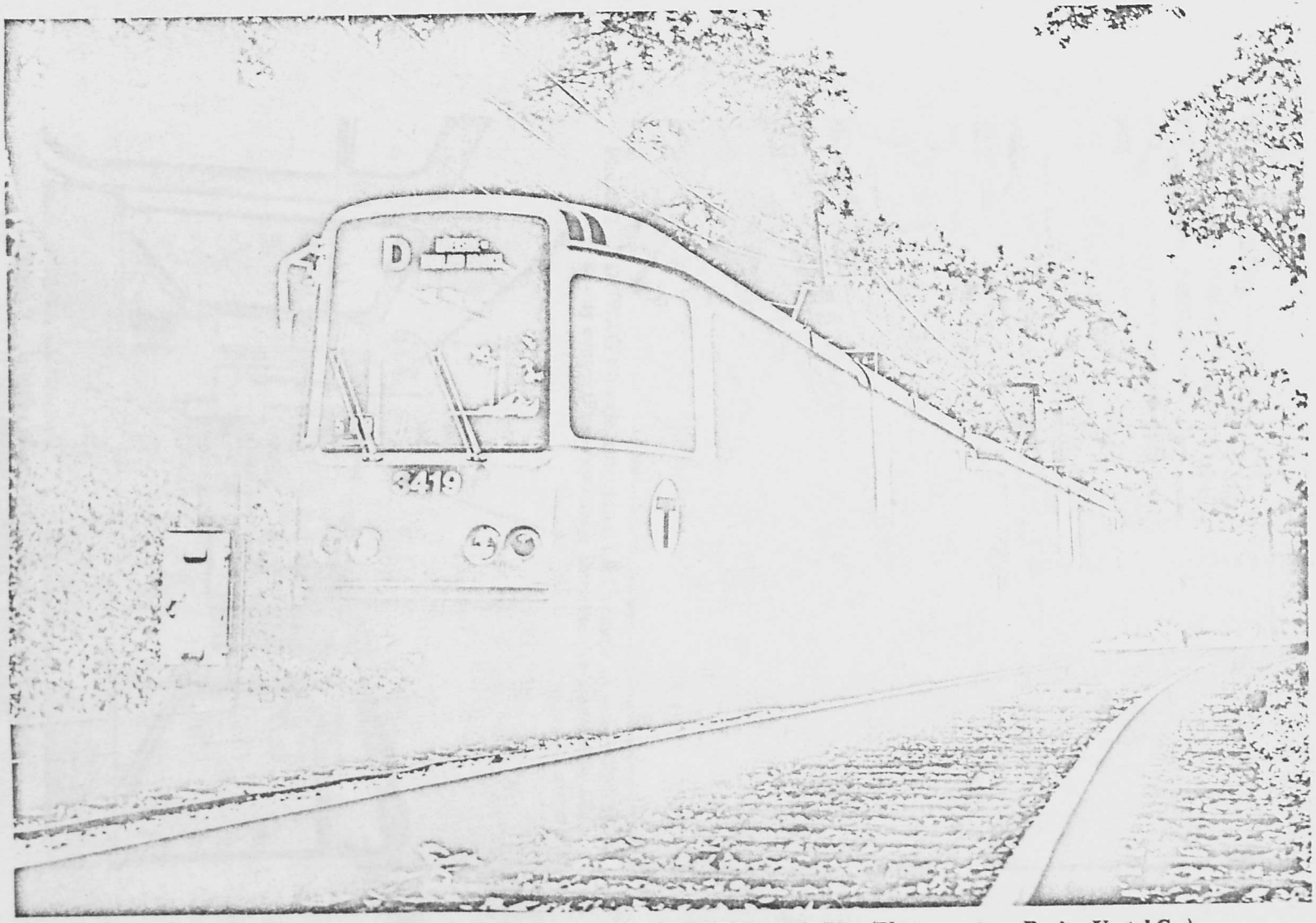

Photo. 1 Two-car train of 6-axle articulated cars on Boston's LRT Riverside Line (Photo courtesy: Boeing Vertol Co.).

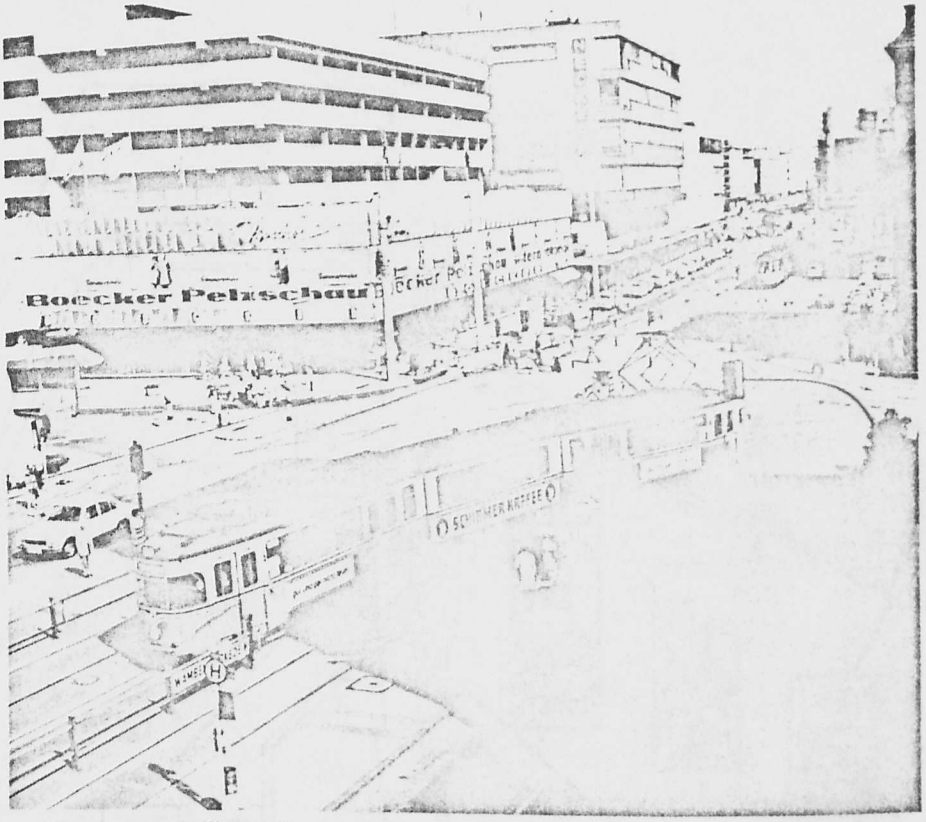

Photo. 2 DÜWAG's 8-axle articulated LRT vehicle on reserved median in city center (Photo courtesy: Dortmunder Stadtwerke AG).

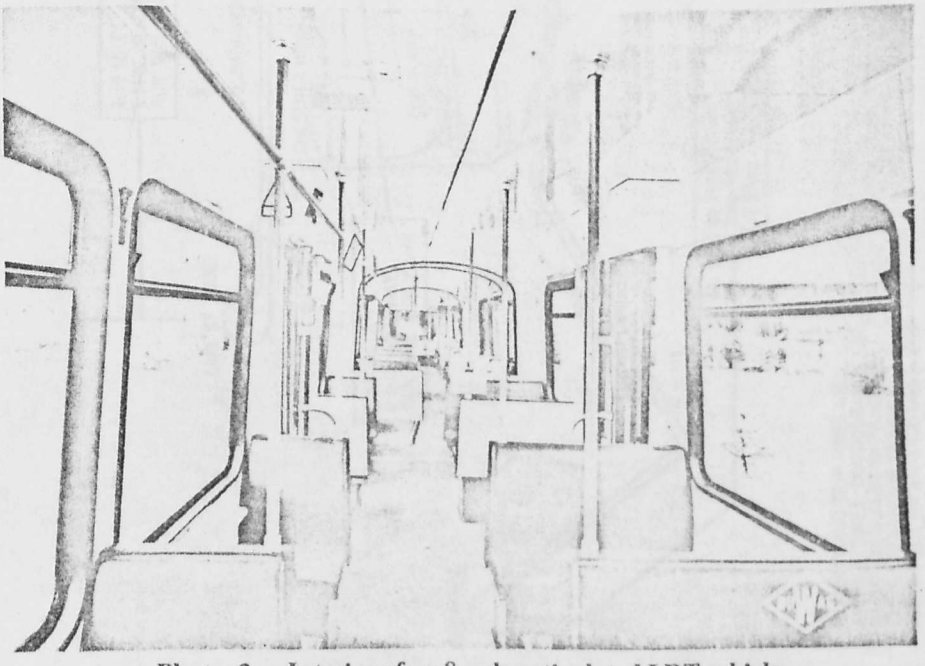

Photo. 3 Interior of an 8-axle articulated LRT vehicle (Photo courtesy: DÜWAG, Düsseldorf).

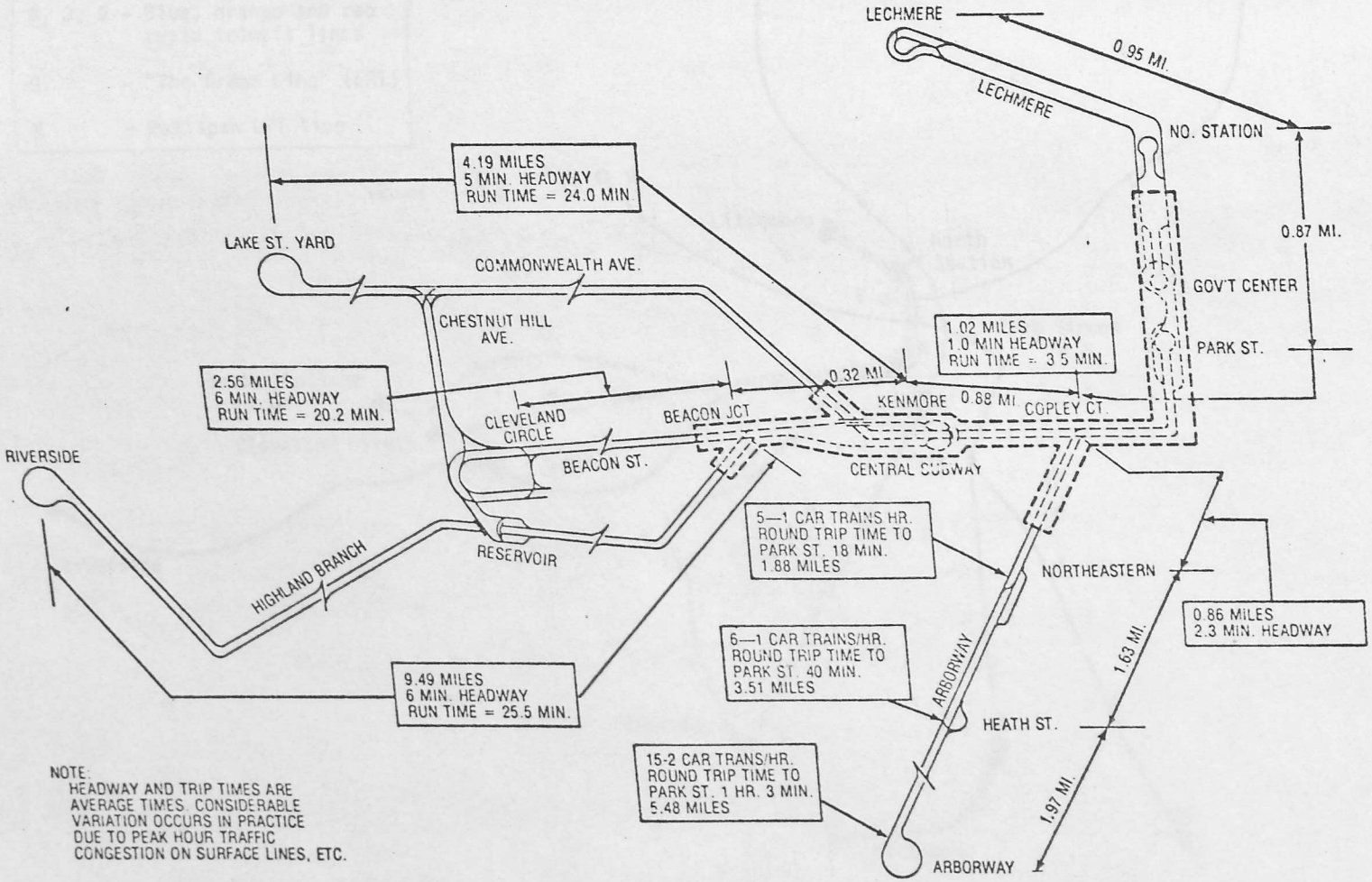

Fig. 1. Track layout and operating data of the Boston's LRT system. (Source: Reference [10])

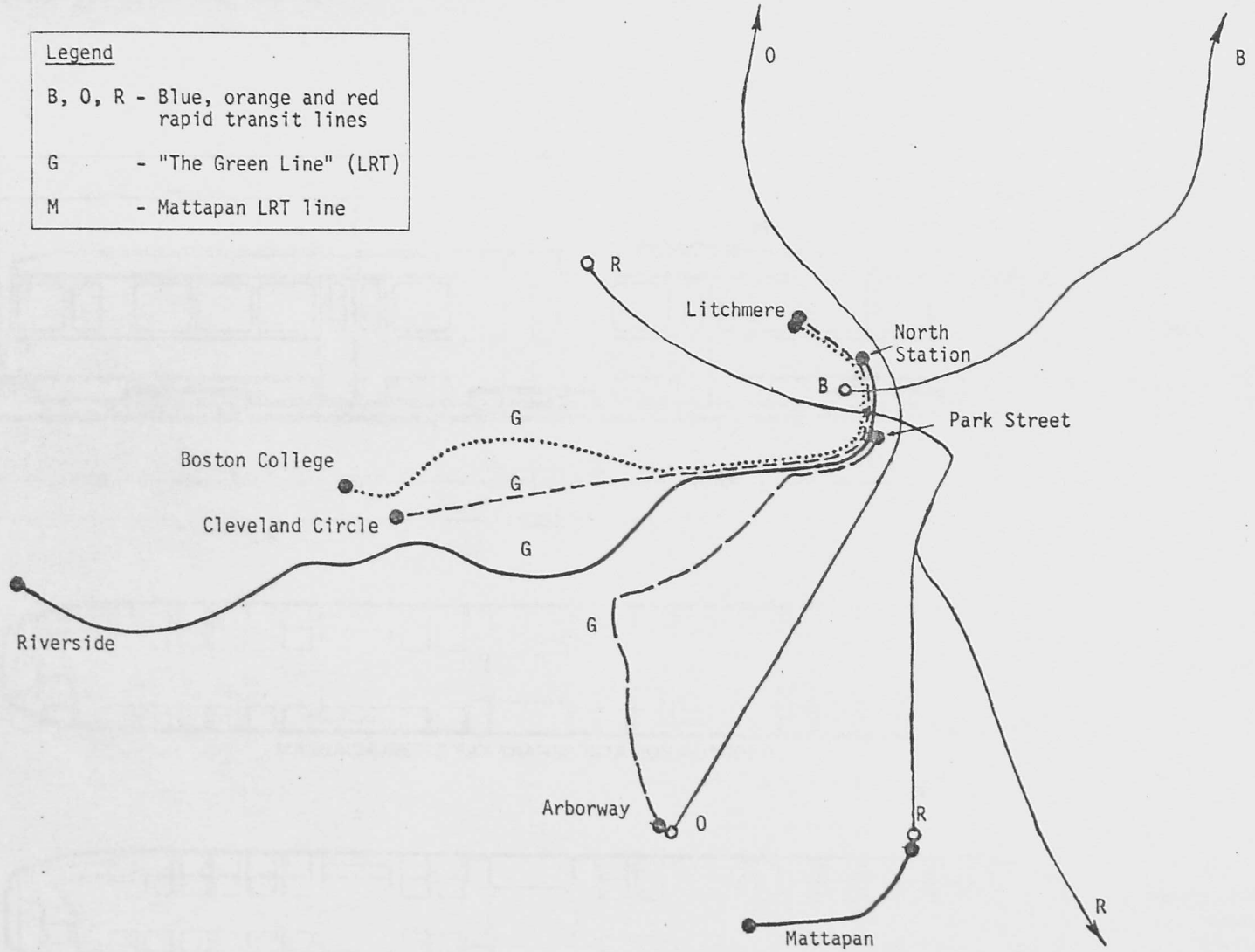

Fig. 2 Rail transit lines in Boston

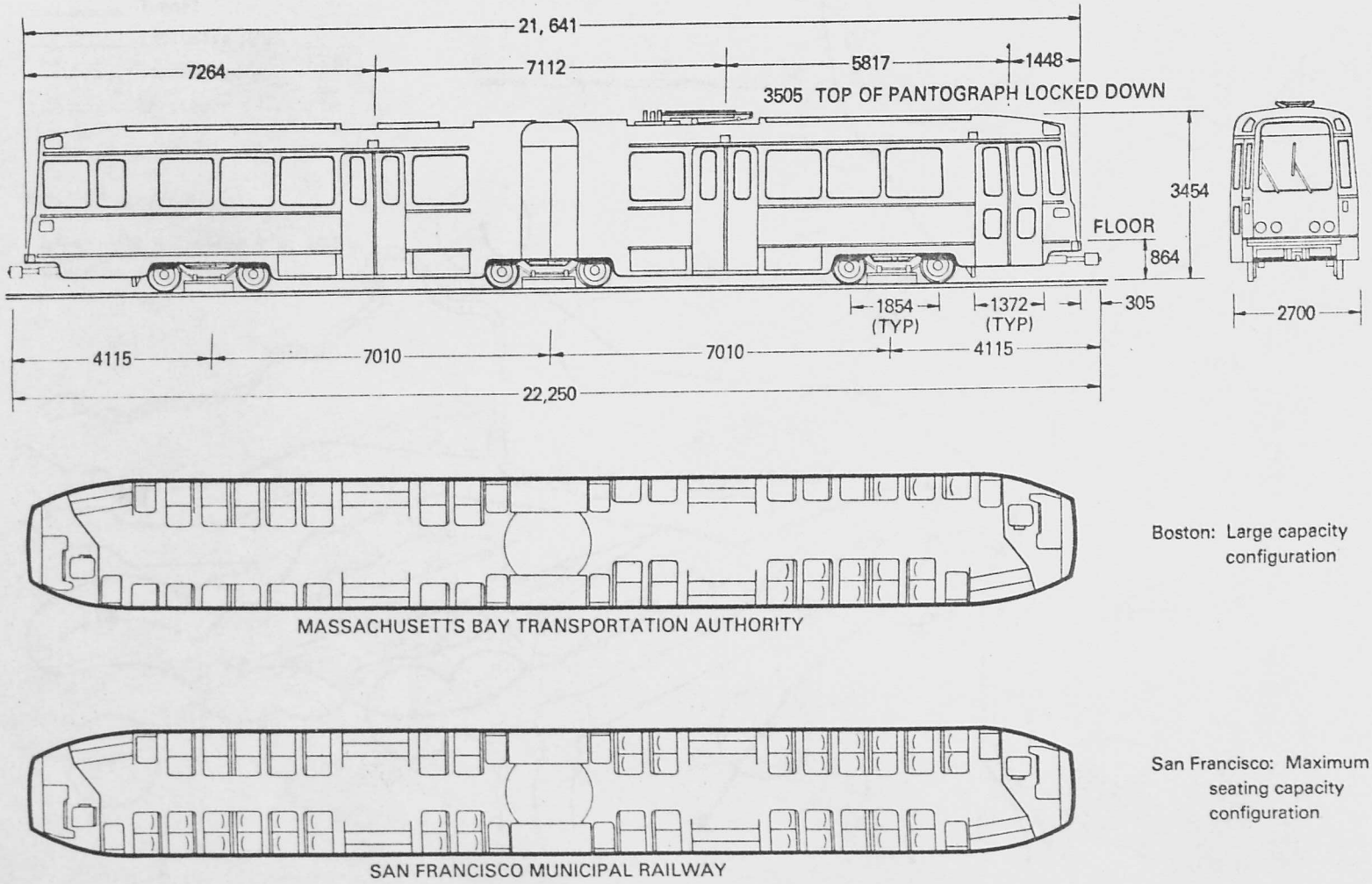

Fig. 3 Boeing's 6-axle articulated vehicle for Boston and San Francisco. (Source: Reference [2])

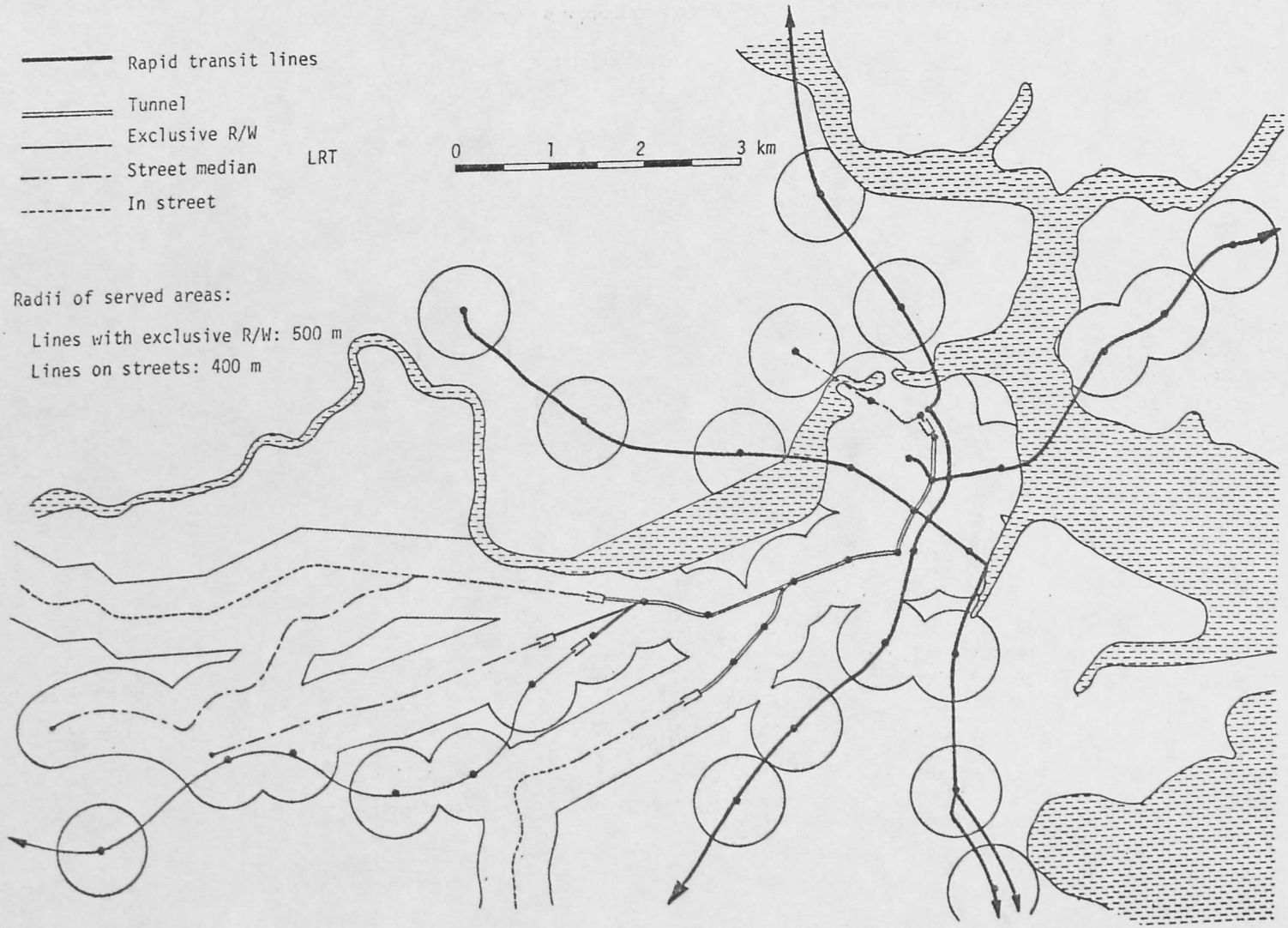

Fig. 4 Rail transit lines in Boston and their service areas.